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Laparoscopic versus open appendectomy in adults and children: A meta-analysis of randomized controlled trials

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Abstract

Objective: The aim of this study was to evaluate the differences of laparoscopic appendectomy (LA) versus open appendectomy (OA) in adults and children.

Methods: Randomized controlled trials (RCTs) comparing LA and OA in adults and children between January 1992–March 2016 were included in this study. A meta-analysis was performed to evaluate wound infection, intra-abdominal abscess, postoperative complications, reoperation rate, operation time, postoperative stay, and return to normal activity.

Result: Thirty-three studies including 3642 patients (1810 LA, 1832 OA) were included. Compared with OA, LA in adults was associated with lower incidence of wound infection, fewer postoperative complications, shorter postoperative stay, and earlier return to normal activity, but a longer operation time. There was no difference in levels of intra-abdominal abscess and reoperation between the groups. Subgroup analysis in children did not reveal significant differences between the two techniques in wound infection, postoperative complications, postoperative stay, and return to normal activity.

Conclusion: LA in adults is worth recommending as an effective and safe procedure for acute appendicitis, and further high-quality randomized trials comparing the two techniques in children are needed.

Keywords

Appendectomy, laparoscopic surgery, open surgery, meta-analysis

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Introduction

Acute appendicitis is a common cause of acute abdominal pain with a life-time incidence between 7–9%.[1] As a direct result, appendectomy is one of the most frequently performed surgical procedures. The open approach to appendectomy was originally described by McBurney.[2] It has become the standard treatment of choice for acute appendicitis, remaining mainly unchanged for 100 years due to its favorable efficacy and safety. Since the advent of laparoscopy, appendectomy has increasingly been performed using a minimally invasive approach, following the first report by Semm in 1983.[3] Although laparoscopic appendectomy (LA) has gained much popularity among some surgeons, others remain skeptical with regard to replacing the relatively straightforward open appendectomy (OA). Criticism of LA includes increased operative cost, primarily due to the use of disposable laparoscopic instruments,[4] increased operation time, and concerns about a higher incidence of intra-abdominal abscesses, particularly after perforated appendicitis.[5] Proponents of LA, however, claim that the advantages of the procedure include improved wound healing, reduced postoperative pain and, ultimately, earlier discharge from hospital, all translating to an earlier return to normal activity. Therefore, the use of LA remains controversial, in contrast to the wide acceptance of laparoscopic cholecystectomy since its innovation.

Meta-analysis is a useful statistical tool that can be used to evaluate the existing literature in both quantitative and qualitative ways by comparing and integrating the results of different studies, taking into account variations in characteristics that can influence the

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overall estimate of the outcome of interest. Previous meta-analyses have demonstrated a reduced incidence of surgical site infection and length of hospital stay following LA in adults.[6,7] Some studies, however, have suggested that LA is associated with higher rates of intra-abdominal abscess formation, longer operative times, and higher surgical costs when compared to OA.

LA, however, is currently not universally accepted as the standard of care for the treatment of acute appendicitis in children and differences in the patient population mean that direct extrapolation of adult data to children is invalid.[8,9] Although much research has been done to compare results from LA and OA in children, conclusions have been difficult to draw because of small study size, the presence of only a handful of randomized trials, and possible heterogeneity in patient characteristics, surgical practice, and severity of appendicitis between these studies. At present, there is no consensus between pediatric surgeons as to the benefits of LA over OA.

In order to guide future management decisions, we decided to conduct a meta-analysis of randomized controlled trials (RCTs) comparing LA and OA in adult and pediatric patients.

Methods

Selection criteria

A comprehensive literature search of the Cochrane Controlled Trials Register on The Cochrane Library, MEDLINE, EMBASE, and the China Biological Medicine Database (CBMdisc) under the headings of "appendicitis," "appendectomy," "laparoscopy," and "laparoscopic appendectomy" was performed electronically for the period between January 1992–March 2016. The reference lists of pertinent reviews and retrieved articles was checked for additional study identification. In the meta-analysis, the following inclusive selection criteria were set and reviewed by two independent investigators: (a) each trial should be a prospective randomized controlled clinical trial; (b) compare LA and OA techniques; (c) report on at least one of the outcome measures mentioned below. The following exclusive selection criteria were set: (a) non-randomized studies; (b) repeated reports if more than one version of the same study was retrieved, only the most recent one was used; (c) studies in which the standard deviation of the mean for continuous outcomes of interest were not reported. The studies were independently evaluated by the two authors, outcome measures were wound infection, intra-abdominal abscess, postoperative complications, reoperation, operation time, postoperative stay, and return to normal activity. Discrepancies in the evaluation of some studies were resolved through discussion between the reviewers.

Assessment of study quality

Quality of included reports was scored using the Jadad composite scale,[10] which assesses descriptions of randomization, blinding, and dropouts (withdrawals) in reports. The quality scale ranges from 0–5 points with a low quality report of score at two or less and a high quality report of score at least three.

Statistical analysis

The analysis was completed using Review Manager software (Rev Man 5.3) from the Cochrane collaboration. Continuous data presented in the same scale were analyzed using weight mean difference (WMD) with 95% confidence intervals (CIs). Due to the rarity of some events, dichotomous data were analyzed using Peto odds ratios (ORs). A randomized effect model was used due to the clinical heterogeneity of the included studies. Heterogeneity was evaluated using the chi-square test. All p values less than 0.05 were considered significant for heterogeneity. A p value less than 0.05 was considered significant for overall effects. Funnel plots were used to investigate any possible publication bias in the meta-analysis.

Results

Description of studies

The initial literature search identified 661 studies, based on the inclusion criteria 621 studies were excluded, giving a selection of 40 studies for more detailed review. Seven of those studies were subsequently excluded (Figure 1), and only 33 RCTs that exclusively evaluated LA and OA and fitted the inclusion and exclusion criteria were selected.[11–43] Study characteristics and quality evaluation of each selected study are shown in Table 1, they were homogeneous in clinical and methodological criteria. The RCTs selected included 3642 patients, of whom 1810 were laparoscopic and 1832 were open procedures. There are only 426 children, all of the others are adults.

Wound infection

Twenty-nine trials reported the incidence of wound infection in adults and children, and the wound infection rate was 51 in 1696 (3.01%) patients in LA and 130 in 1727 (7.53%) patients in OA. A fixed-effects model was used because there was no heterogeneity between the two groups ($I^2 = 4\%$, $p = 0.40$). Wound infection

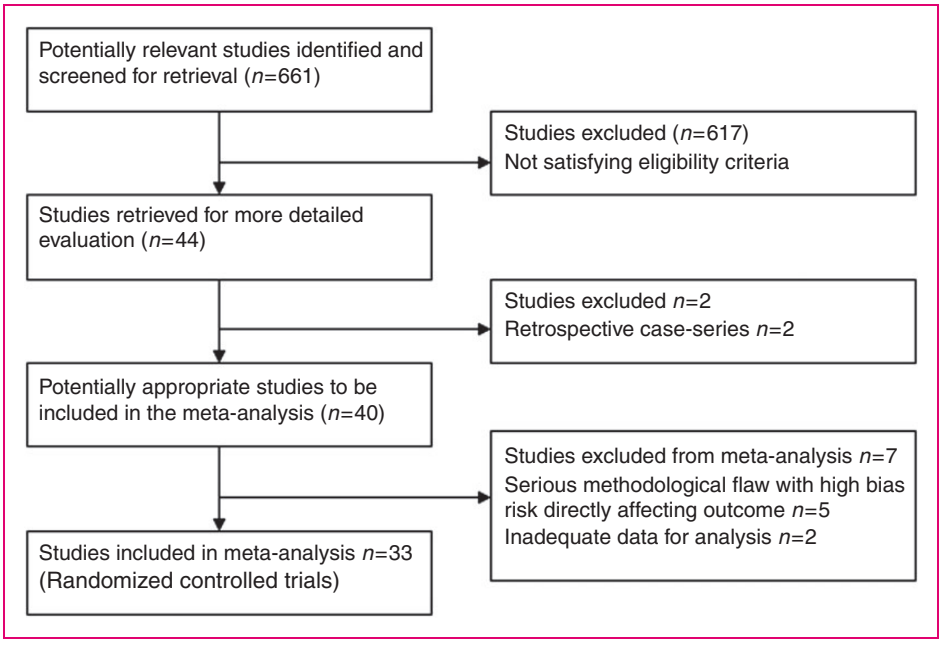

Figure 1. Procedure for identification and selection of studies.

was significantly reduced with LA versus OA (OR = 0.38, 95% CI: 0.28–0.53, $p < 0.00001$). A subcategory analysis of wound infection in adults was performed, the results showed that LA was associated with a significantly reduced incidence of wound infection (OR = 0.38, 95% CI: 0.27–0.54, $p < 0.00001$). However, a subcategory analysis of wound infection in children showed that there was no significant difference between the two groups (OR = 0.39, 95% CI: 0.12–1.25, $p = 0.11$) (Figure 2).

Intra-abdominal abscess

Eighteen trials reported the incidence of intra-abdominal abscess in adults and children. A fixed-effects model was used because there was no heterogeneity between the two groups ($I^2 = 0\%$, $p = 0.80$). Thirty-three (3.17%) and 40 (3.77%) incidences of postoperative intra-abdominal abscess were seen in the laparoscopic and open procedure groups, respectively, and there was no significant difference between the two groups (OR = 0.84, 95% CI: 0.55–1.28, $p = 0.41$). A subcategory analysis of intra-abdominal abscess in adults or children showed that there was no significant difference between the two groups (OR = 0.78, 95% CI: 0.50–1.23, $p = 0.29$, and OR = 1.43, 95% CI: 0.40–5.14, $p = 0.58$, respectively) (Figure 3).

Postoperative complications

Twenty-eight trials reported the incidence of postoperative complications in adults and children, and the postoperative complications rate was 151 in 1595 (9.47%) patients in LA and 240 in 1628 (14.74%) patients in OA. A random-effects model was used because there was heterogeneity between the two groups ($I^2 = 47\%$, $p = 0.004$), however, a subcategory analysis of postoperative complications in children showed that there was no heterogeneity between the two groups ($I^2 = 0\%$, $p = 0.80$). When we modified to the fixed-effects model, the results were the same to previous results, the p value not changed. Postoperative complications were significantly reduced with LA versus OA (OR = 0.64, 95% CI: 0.44–0.93, $p = 0.02$). A subcategory analysis of postoperative complications in adults was performed, and the results showed that LA was associated with a significantly reduced incidence of postoperative complications (OR = 0.62, 95% CI: 0.40–0.96, $p = 0.03$). However, a subcategory analysis of postoperative complications in children showed that there was no significant difference between the two groups (OR = 0.74, 95% CI: 0.34–1.59, $p = 0.44$) (Figure 4).

Reoperation

Twelve trials reported the incidence of reoperation in adults and children. A fixed-effects model was used because there was no heterogeneity between the two groups ($I^2 = 0\%$, $p = 0.90$). Eighteen (2.36%) and 17 (2.11%) incidences of reoperation were seen in the laparoscopic and open procedure groups, respectively, and there was no significant difference between the two groups (OR = 1.08, 95% CI: 0.58–2.01, $p = 0.80$).

Table 1. Study characteristics and quality evaluation of each selected study

Study first author	Jadad score	Randomization	Double blind	Lost to follow-up	Sample size	Patients	Conversion rate (%)
Martin[11]	2	1	1	0	169	Adults	16.1
Macarulla[12]	4	2	2	0	210	Adults	8.3
Minne[13]	4	2	1	1	50	Adults	7.4
Reiertsen[14]	3	2	1	0	84	Adults	ND
Hellberg[15]	5	2	2	1	500	Adults	12
Shirazi[16]	2	1	1	0	60	Adults	ND
Moberg[17]	5	2	2	1	163	Adults	2.5
Kaplan[18]	4	2	2	0	100	Adults	0
Wei[19]	3	1	1	1	220	Adults	0
Ignacio[20]	4	2	2	0	52	Adults	3.8
Mutter[21]	3	1	2	0	100	Adults	12
Cox[22]	3	1	1	1	64	Adults	15
Tzovaras[23]	5	2	2	1	147	Adults	22
Laine[24]	2	1	1	0	50	Adults	8
Mulhim[25]	4	2	1	1	60	Adults	10
Dalen[26]	3	2	1	0	63	Adults	ND
Clarke[27]	3	1	2	0	37	Adults	ND
Kargar[28]	4	2	2	0	100	Adults	0
Schietroma[29]	4	2	2	0	147	Adults	5.4%
Khalil[30]	5	2	2	1	147	Adults	1.39%
Gilchrist[31]	2	1	1	0	64	Children Not report	ND
Lejus[32]	3	1	2	0	63	Children 8–15 years	0
Hay[33]	3	1	1	1	82	Children 4–12 years	0
Lavonius[34]	4	2	1	1	43	Children 7–15 years	4
Lintula[35]	5	2	2	1	61	Children 4–15 years	ND
Little[36]	3	2	1	0	88	Children 1–16 years	7
Lintula[37]	5	2	2	1	25	Children 4–15 years	0
Kocatas[38]	4	2	1	1	96	Adults	ND
Rashid[39]	3	2	1	0	100	Adults	0
Thomson[40]	5	2	2	1	112	Adults	3.3
Cipe[41]	3	2	1	0	241	Adults	0
Mantoglu[42]	3	2	1	0	63	Adults	ND
Taguchi[43]	5	2	2	1	81	Adults	2.4%

ND: not described.

A subcategory analysis of reoperation in adults or children showed that there was no significant difference between the two groups (OR = 1.01, 95% CI: 0.51–1.98, $p = 0.99$, and OR = 1.56, 95% CI: 0.35–6.86, $p = 0.56$, respectively) (Figure 5).

Operation time

Eighteen trials reported the operation time in adults and children. A random-effects model was used because there was heterogeneity between the two groups ($I^2 = 96\%$, $p < 0.00001$), however, a subcategory analysis of operation time in children showed that there was no heterogeneity between the two groups ($I^2 = 0\%$, $p = 0.60$). When we modified to the fixed-effects model, the results were the same to previous results, the p value was not changed. LA was associated with a significantly increased length of operation time (WMD = 11.59, 95% CI: 6.65–16.53, $p < 0.0001$). A subcategory analysis of operation time in adults or children showed that LA was associated with a significantly increased length of operation (WMD = 10.49, 95% CI: 5.05–15.92, $p = 0.0002$, and WMD = 16.91, 95% CI: 11.96–21.86, $p < 0.00001$, respectively) (Figure 6).

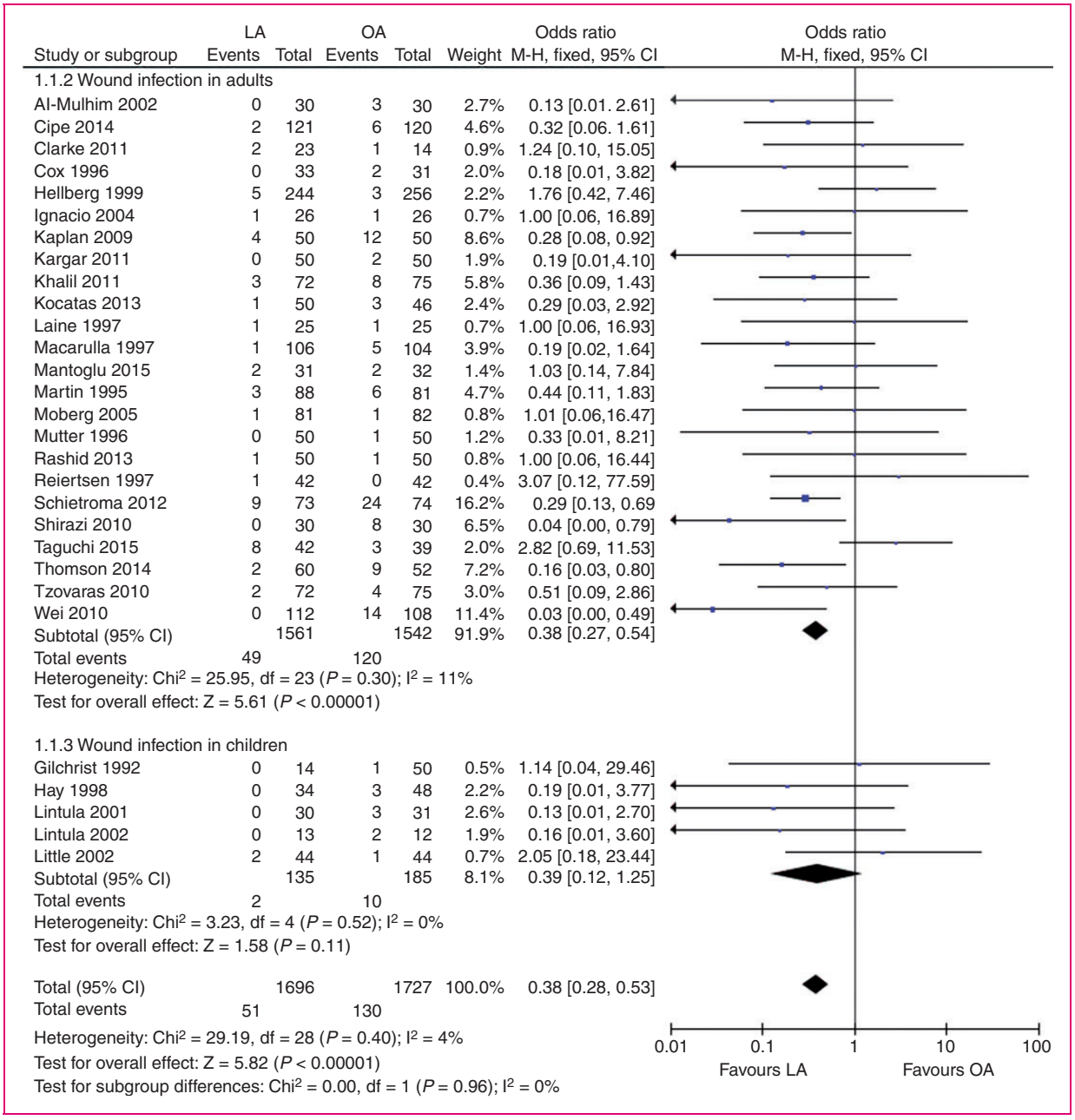

Figure 2. Meta-analysis of wound infection. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

Postoperative stay

Seventeen trials reported the postoperative stay time in adults and children, and postoperative stay time was significantly reduced with LA versus OA (WMD = −0.79, 95% CI: −1.35– −0.23, $p = 0.006$). A random-effects model was used because there was heterogeneity between the two groups ($I^2 = 98\%$, $p < 0.00001$). A subcategory analysis of postoperative stay time in adults was performed, and the results showed that LA was associated with a significantly reduced postoperative stay time (WMD = −0.78, 95% CI: −1.38– −0.17, $p = 0.01$). However, a subcategory analysis of postoperative stay time in children showed that there was no significant difference between the two groups (WMD = −0.83, 95% CI: −2.46–0.81, $p = 0.32$) (Figure 7).

Return to normal activity

Nine trials reported the return to normal activity time in adults and children, and return to normal activity

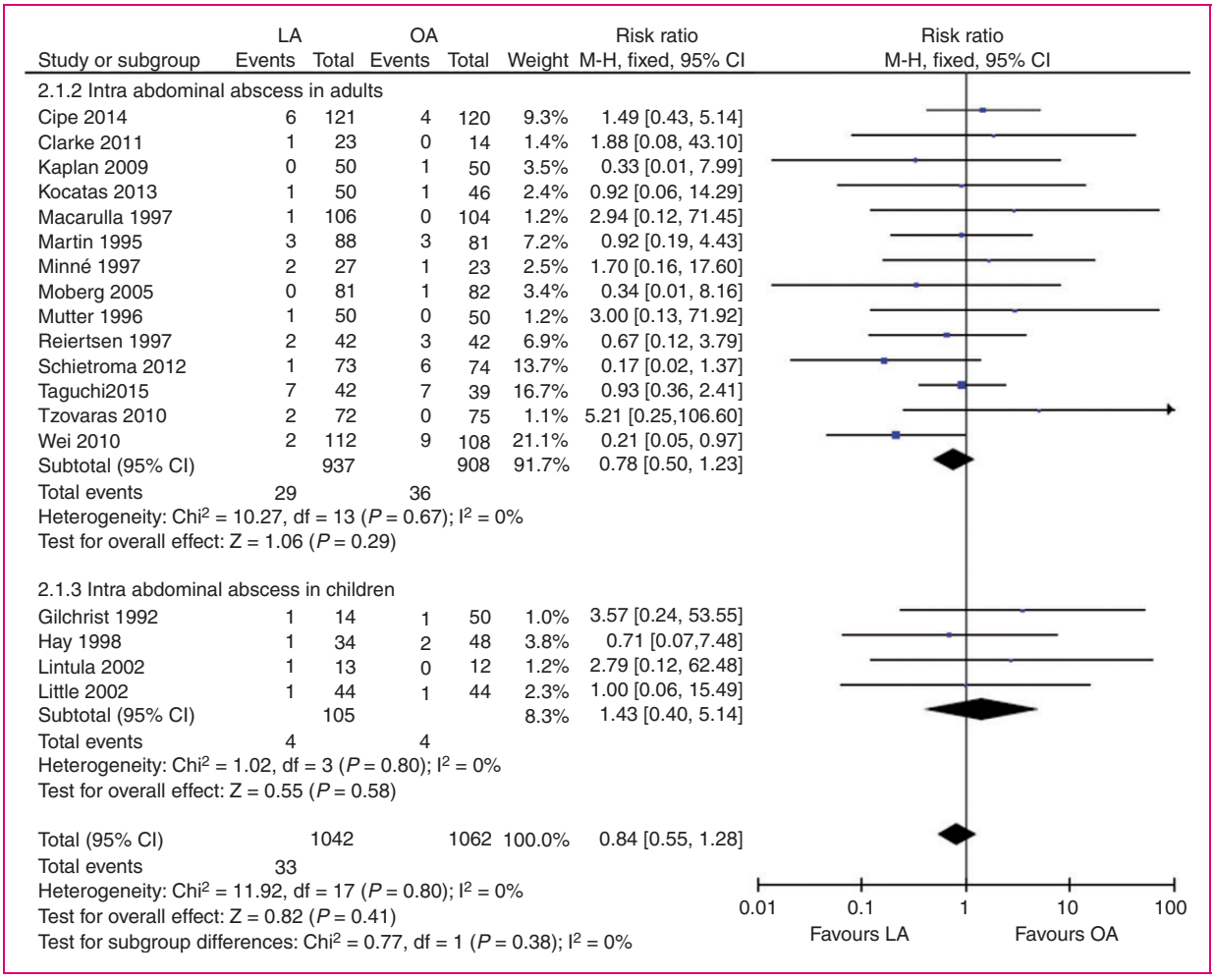

Figure 3. Meta-analysis of intra-abdominal abscess. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

time was significantly reduced with LA versus OA (WMD = −5.45, 95% CI: −8.98– −1.91, $p = 0.003$). A random-effects model was used because there was heterogeneity between the two groups ($I^2 = 99\%$, $p < 0.00001$). A subcategory analysis of return to normal activity time in adults was performed, and the results showed that LA was associated with a significantly reduced return to normal activity time (WMD = −3.92, 95% CI: −6.15– −1.70, $p = 0.0006$). However, a subcategory analysis of return to normal activity time in children showed that there was no significant difference between the two groups (WMD = −11.43, 95% CI: −22.94–0.09, $p = 0.05$) (Figure 8).

Sensitivity analysis

We carried out a sensitivity analysis by adding one study at a time and leaving one study out in turn, and the results were the same to previous results, the p value was not changed (data not shown).

Publication bias

Funnel plots were used to investigate any possible publication bias in the meta-analysis. Since there were only a small number of children studies discussing intra-abdominal abscess, postoperative stay, reoperation, and return to normal activity, a funnel-plot analysis was used to detect possible publication bias only for wound infection and postoperative complications. The included studies fell symmetrically on both sides of the horizontal line (real value), indicating that there was no obvious publication bias related to these studies, and also indicating that the meta-analysis was reliable (data not shown).

Discussion

In the wake of the spectacular success of laparoscopic cholecystectomy, many surgeons have been eager to extrapolate the proven benefits of minimal access surgery to other procedures, including appendectomy.

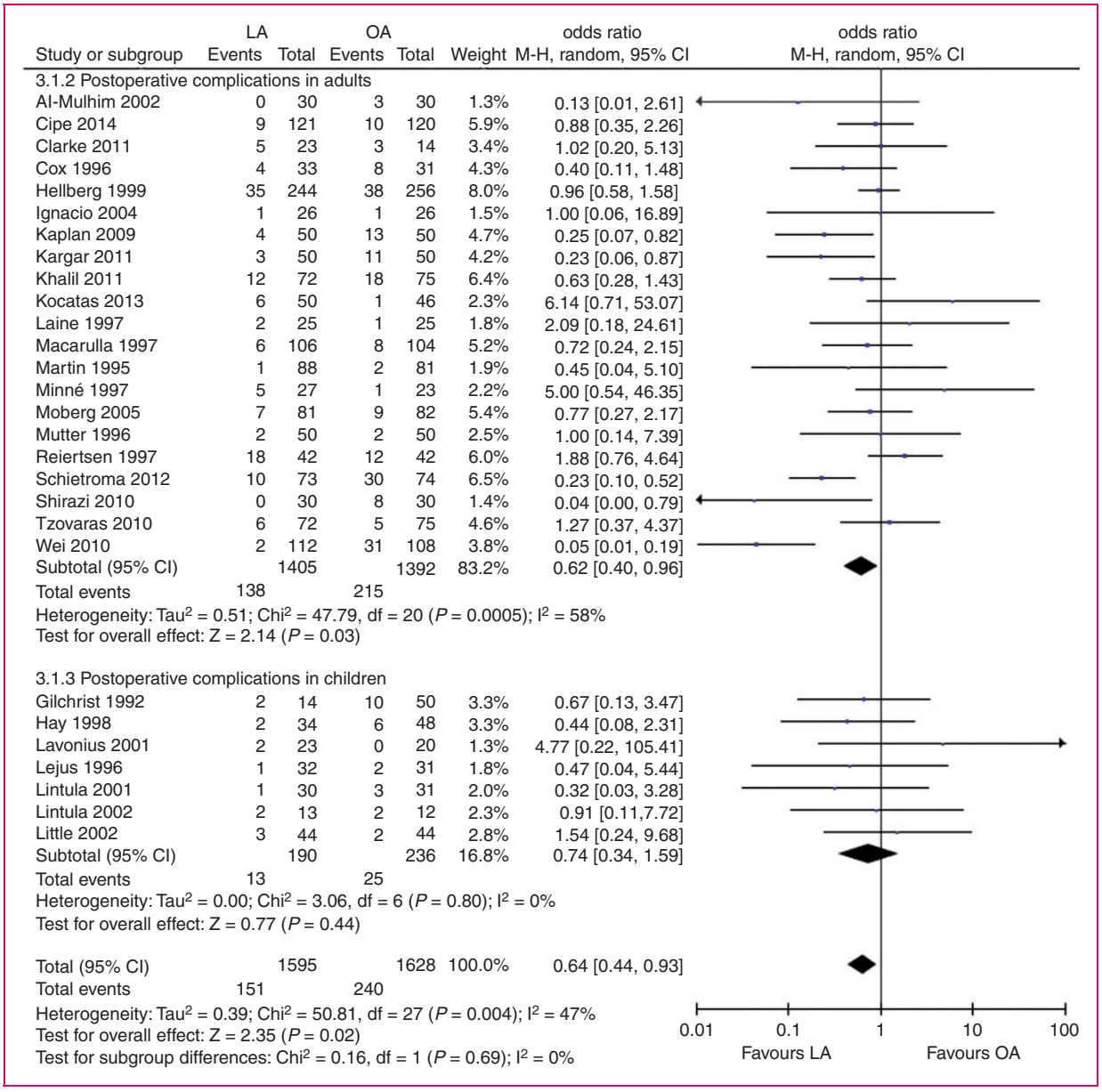

Figure 4. Meta-analysis of postoperative complications. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

First performed by Semm in 1983, LA increased in popularity throughout the 1990s. However, unlike cholecystectomy, the benefits of the laparoscopic approach have not been as apparent.

Meta-analysis is a relatively new and increasingly popular method of data analysis. It is especially valuable when previous studies have been unable to show significant differences between treatments because of small sample sizes, or when there is no consensus of opinion. The results of this meta-analysis show that, when compared with OA, LA in adults was associated with lower incidence of wound infection, fewer postoperative complications, shorter postoperative stay, and earlier return to normal activity, but a longer operation time, there was no difference in levels of intra-abdominal abscess and reoperation between the groups. However, subgroup analysis in children did not reveal significant differences between the two techniques in wound infection, postoperative complications, postoperative stay, and return to normal activity.

Wound infection is the most common complication after appendectomy, although the answer to the question as to why wound infection might be reduced during LA is unclear. A possible reason for this is that in open appendectomies the appendix is delivered directly through the wound, thereby risking

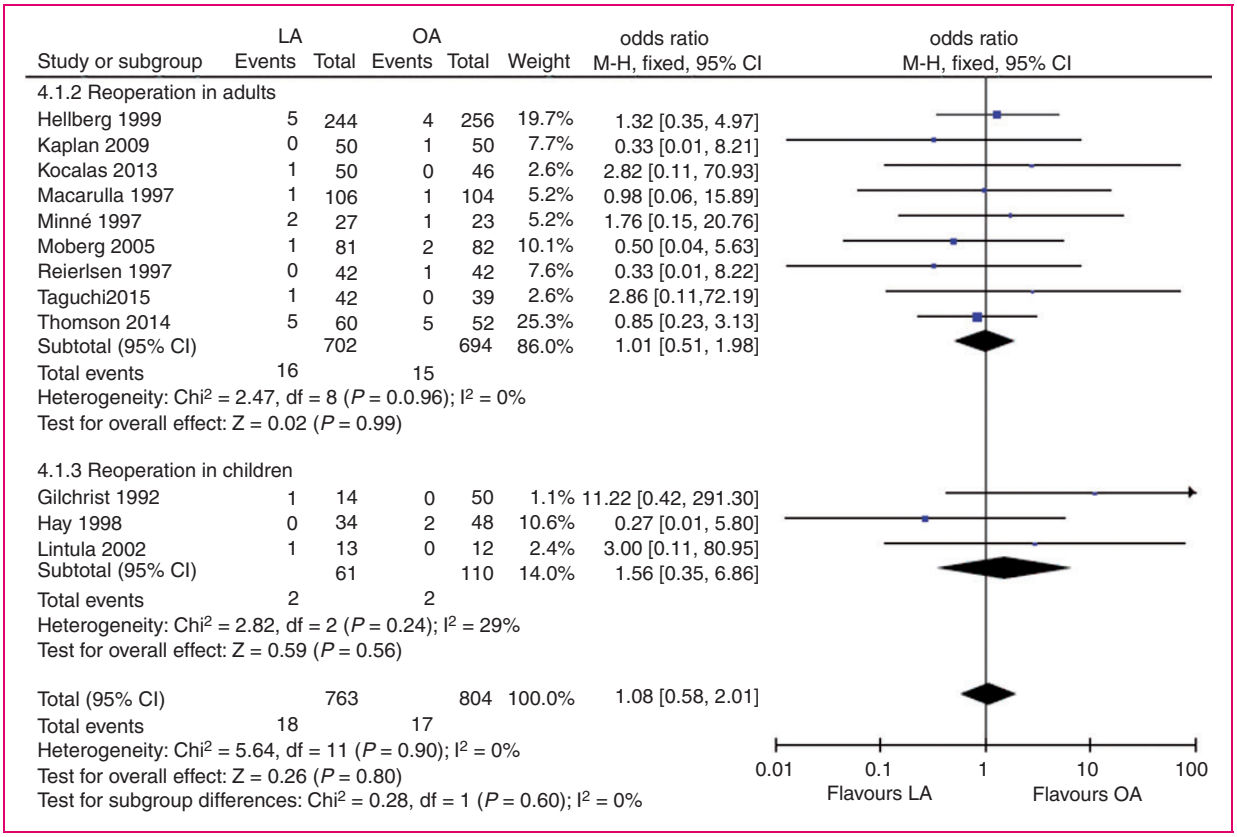

Figure 5. Meta-analysis of reoperation. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

contamination, whereas in laparoscopic surgery the inflamed appendix never comes in to contact with the wound as it is removed via a trocar or bag. This advantage might be magnified in obese patients, where a larger open incision would be necessary, with its attendant risks of greater infection and postoperative pain.[44]

The one serious disadvantage to LA is the possibly greater incidence of intra-abdominal abscess formation. In a retrospective review, Tang and coauthors[5] evaluated the incidence of postoperative intra-abdominal abscess formation after LA and OA. In patients with perforated appendicitis, they found a strong trend toward an increased rate of abscesses in the patients treated laparoscopically. We were not able to analyze the incidence of intra-abdominal abscesses in the subset of patients with perforation because such data were not reported. This meta-analysis did not show a statistically significant increase in the rate of intra-abdominal abscess formation in the LA group.

Postoperative complications are usually considered in an assessment of a procedure's safety. The common complications of appendectomy are wound infection, intra-abdominal abscess, postoperative ileus, bleeding, and the like. In this meta-analysis, we used the overall incidence of postoperative complications to assess the safety of LA. The meta-analysis results showed that the overall incidence of postoperative complications in LA group was lower than in the OA group ($Z = 2.35$; $p = 0.02$).

Results for meta-analysis of operation time showed that LA took longer than OA by 11.59 min (WMD = 11.59, 95% CI: 6.65–16.53, $p < 0.00001$). Considering the increased instrumentation used during laparoscopic surgery and the setup time involved, the concept of a laparoscopic procedure taking longer than its open equivalent is not surprising, however, the slightly longer operation time with the additional 11.59 min in LA will most probably be reduced over time, as surgeons become more adept at the procedure. Pier and associates[45] reported a series of 625 LA cases in which the average operating time was 15–20 min. Length of postoperative stay results from the studies included in this meta-analysis showed that LA in adults significantly reduced length of postoperative stay as compared with OA by 0.79 days. These results may be due to the fact that mobilization following LA is improved, thereby facilitating recovery and subsequent discharge from hospital. Early return to normal activity is accepted as an obvious advantage of LA, which was supported by a large scale meta-analysis conducted by the Cochrane Colorectal Cancer Group.[6] The trocar incisions of LA contribute to

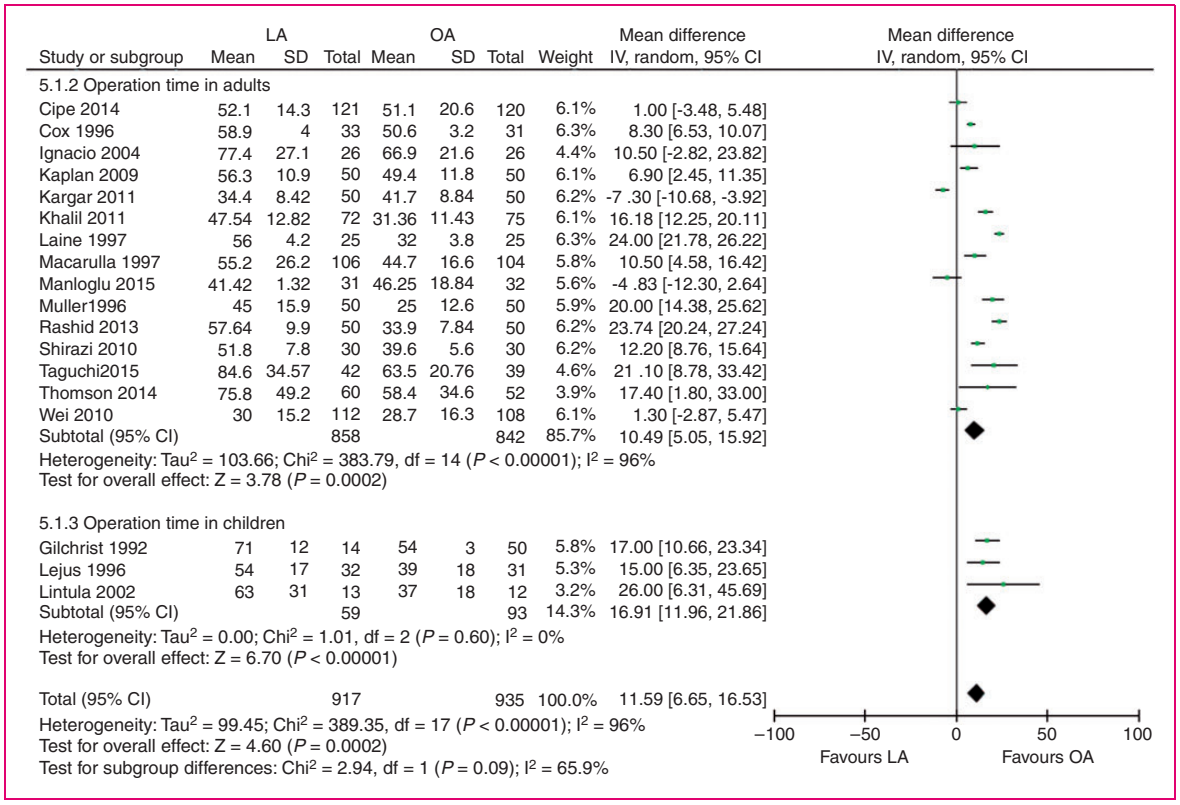

Figure 6. Meta-analysis of operation time. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

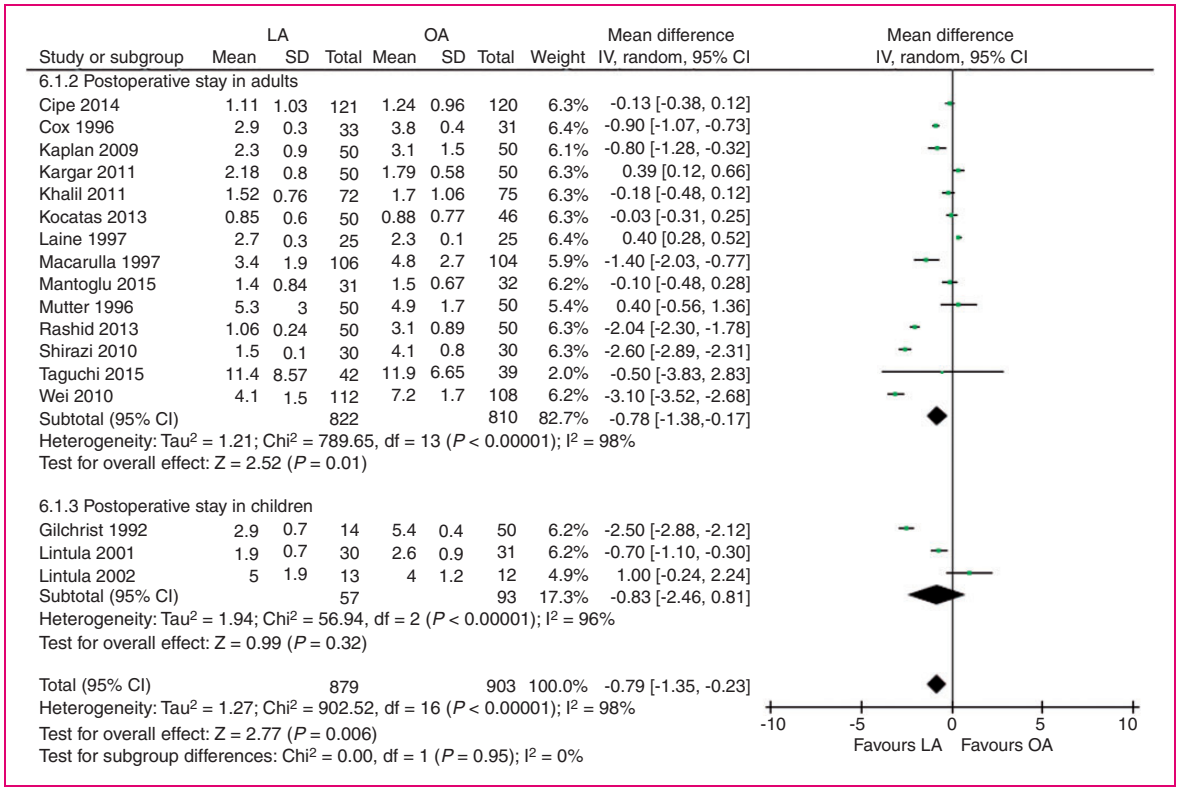

Figure 7. Meta-analysis of postoperative stay. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

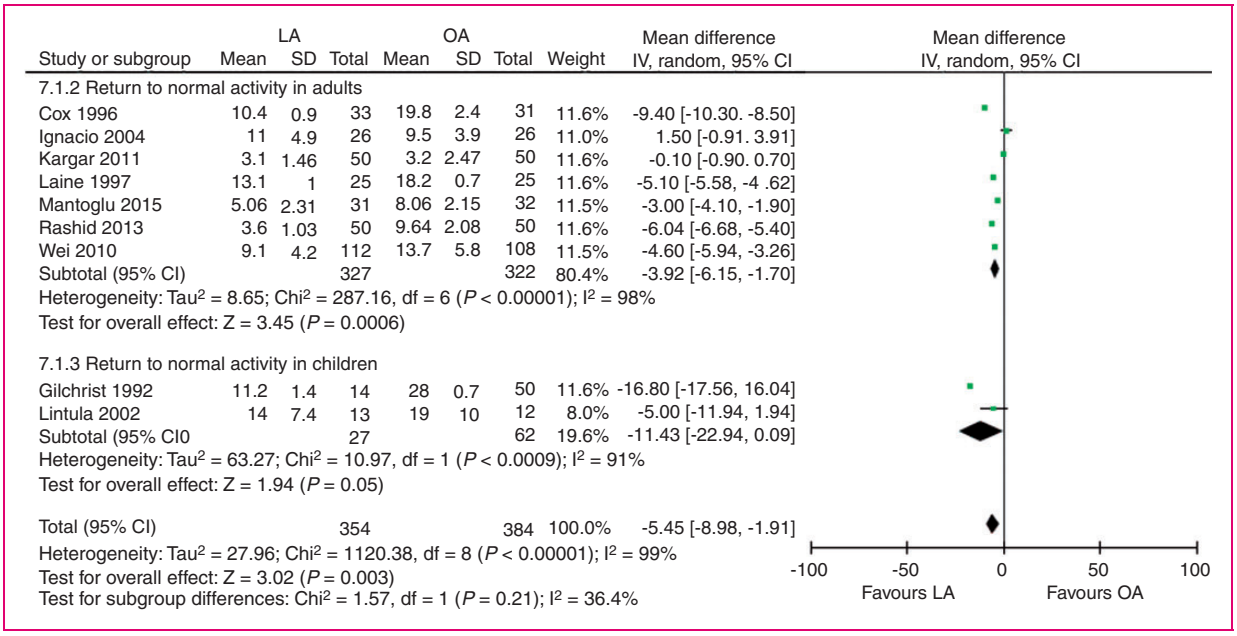

Figure 8. Meta-analysis of return to normal activity. CI: confidence interval; LA: laparoscopic appendectomy; OA: open appendectomy.

minimal trauma to the abdominal wall and less pain, allowing faster recovery.[46]

There are other potential benefits to performing LA, including the ability to perform routine diagnostic laparoscopy. This may be of value in equivocal cases or in women,[47] and laparoscopy has been shown to reduce the incidence of negative appendectomies.[48–51] The practice of not removing a normal looking appendix is controversial, however, and there is evidence that visual inspection at the time of surgery cannot accurately predict the true histopathologic findings.[52]

This study has several limitations. First, the different operation methods were performed by different surgeons in different countries; thus, different learning curves may have contributed to the reported difference between the two procedures. Second, because of ethical limitations or other reasons, the studies of children are few, and the sample size in some studies are rather small. Third, the Jadad composite scale of some studies are low, which indicates the quality of included reports are not high.

The current meta-analysis showed that although LA has a longer operative time, it results in faster postoperative rehabilitation, a shorter hospital stay, and fewer postoperative complications than OA. Thus the LA is a useful tool in the treatment of acute appendicitis and worth recommending as an effective and safe procedure for adults. However, the advantage of LA in children was not obvious. Therefore, the study further highlights that more large sample and high-quality randomized trials for children are needed.

Conflict of interest

None of the authors have any conflicts of interest to declare.

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